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16. ABSTRACT North American meteorological and sulfur emissions data for 1980 have been processed to serve as input data to regional acid deposition models participating in the International Sulfur Deposition Model Evaluation (ISDME) Project. Using these data sets, 15 regional acid deposition models are to simulate seasonal and annual ambient concentrations and dry and wet deposition amounts of sulfur dioxide and sulfate. As the main objective of the ISDME Project, simulated sulfur wet deposition amounts are to be compared to measurements at selected sites of five North American precipitation chemistry networks. Discussions focus on the data processing procedures and the 1980 model input data sets.		
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INTERNATIONAL SULFUR DEPOSITION MODEL EVALUATION

- 1980 Standard Model Input Data Set -

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Introduction

Long-range or regional (> 200 km) sulfur deposition models have been developed within the last ten years to estimate ambient sulfur dioxide and sulfate concentrations and wet/dry or bulk sulfur depositions across Europe and North America. The results of some of these models, which do not always concur, have been used to estimate source-receptor relationships on regional and international scales.

Since it is presently not possible to verify these source-receptor relationships, the models at least should be verified using available measurements and a rigorous statistical evaluation. The evaluation should be regarded not only as an assessment of model performance, but also as a means of identifying areas of improvement in the model input data, the model parameterizations and the screening procedures used to select regionally representative evaluation data.

The first concerted international effort to evaluate regional sulfur deposition models in North America was initiated by the United States/Canadian Memorandum of Intent (MOI) on Transboundary Air Pollution (1). During this activity, 8 Lagrangian regional sulfur deposition models simulated ambient sulfur dioxide and sulfate concentrations and sulfate wet and dry deposition amounts for January and July 1978. These simulations then were compared to available measurements.

During these two months of the Sulfate Regional Experiment (SURE), the volume, spatial distribution and temporal resolution (continuous 24-hour averages) of the ambient measurements (2) sufficed. However, up to this time, the small quantity of precipitation chemistry measurements across North America precluded a meaningful evaluation for sulfate wet deposition.

One of the recommendations for further research offered by the MOI Atmospheric Sciences Work Group was to evaluate the 8 MOI models for another year when precipitation chemistry data were more abundant. In response to this recommendation, the U.S. Environmental Protection Agency and Environment Canada organized the International Sulfur Deposition Model Evaluation (ISDME) Project to evaluate up to 15 European and North American models using 1980 North American data.

In the past, the emphasis on model simulations has focused on the modeling aspects themselves; the processing and screening of model input data and model evaluation data have not received the attention they deserve. After all, any deficiencies in the data and data processing procedures ultimately will effect the model results as well as the model evaluation. Therefore, the model input and evaluation data and the data processing/screening procedures have received much attention during this project.

This paper focuses on the available model input data sets, their shortcomings and the data processing approaches used for the ISDME project. The screening procedure for the evaluation data are described elsewhere (3). The model evaluations are to be discussed in a subsequent paper.

Objectives

The main objectives of the ISDME activity are:

- 1) To compile and distribute standard data sets of 1980 North American meteorological and sulfur emissions data to serve as input to operational acid deposition models and
- 2) To evaluate and rank acid deposition models using the 1980 seasonal and annual sulfur wet deposition amounts measured at "regionally representative" sites from the five major North American precipitation chemistry networks.

This activity represents an improvement over the MOI effort to evaluate models by:

- 1) Involving more regional acid deposition models
- 2) Using standardized, quality-controlled input data sets
- 3) Evaluating the models using screened regionally representative precipitation chemistry data (3) as opposed to all sites regardless of their proximity to high emission sources or nearby sample contamination sources.
- 4) Evaluating the models for a year when precipitation chemistry data are available for many more sites
- 5) Evaluating the models for a longer period (one year versus only two months) to yield a more significant statistical evaluation and
- 6) Evaluating the models using more rigorous statistical procedures.

Model Input Data Sets

Basic Model Input Requirements

Existing Eulerian and Lagrangian acid deposition models, because of fundamental differences in their design, require model input data in various forms. Most models require grid point values of meteorological and emissions data. However, those models which are statistical in nature may require some or all of their input to be statistical representations of meteorological parameters (e.g., average duration of wet periods and average trajectories).

Those models which require gridded data may not use the same grid configurations: Grid resolution map projection and orientation can vary. In many cases, the models cannot adapt easily to different grid configurations. Therefore, for the ISDME project, model input data grids were generated in a consistent manner using one common set of data bases for the four grid configurations illustrated in Figure 1.

Basically, these models require three types of input data: Transport winds, precipitation and sulfur dioxide emissions.

Meteorological Data

Transport Winds. Given the fact that upper-air winds are measured only twice per day (early morning and early evening) at sites spaced approximately 350 km apart, detailed diagnostic analyses (e.g., 3-hourly grids with an 80-km resolution for several levels of the boundary layer) from only measured data can have a high degree of uncertainty and a lack of temporal continuity.

Wind analyses from dynamic meteorological models using rawinsonde and satellite data and wind forecasts are a better alternative to these diagnostic analyses for several reasons. First, because the dynamic models include parameterizations of pertinent physical processes, their analyses between measurement sites and for periods between measurement times would be more credible than analyses derived only from interpolations. Second, these dynamic models screen the measurements before using the values in the analyses. Measured wind profiles and time series of data inconsistent with physical laws are excluded or flagged.

Therefore, for ISDME model applications, we selected the 6-hour, 381-km wind analyses produced for the 1000- and 850-mb levels from the Canadian Meteorological Centre (CMC) operational objective analysis of measured and dynamic forecast model wind sets. These 381-km wind grids were interpolated to the finer resolution ISDME configurations (4).

Quality control measures consisted of comparing the 381-km CMC wind analyses to the ISDME configuration analyses for each 6-hour interval of one day in each season. Maximum and minimum speeds for each interval of 1980 were determined for each configuration to identify questionable extremes.

Precipitation. Ideally, since the timing, duration and amount of precipitation are very important factors in simulating wet deposition amounts, one would prefer to use the precipitation data base with the finest spatial and temporal resolution to derive model input data grids. The first data base considered for this activity was the 1980 hourly North American precipitation data base compiled by the National Climatic Center, which consisted of measurements from over 2000 sites. Unfortunately, problems with these data discouraged their use for this activity.

The major problem was discovered after grids of hourly precipitation amounts were generated (Perry Samson, University of Michigan, private communication, 1985). Monthly grids generated by summing hourly amounts for each grid cell depicted numerous cells with unrealistically low values, differing by an order of magnitude from the values at adjacent cells. The cause of this problem was traced to the numerous sites consistently reporting very low amounts. Another problem with this data base was the sparse coverage of Canadian precipitation data, especially during the snow season when many of the sites do not operate.

As an alternative to this data base, the 24-hour, 1980 CMC precipitation grids, with a resolution of 127 km, were selected. Despite the coarser temporal resolution, this data base was superior for several reasons. First, amounts for data-sparse or data-void areas, estimated from ship and remote sensor data, were available. Further, unrealistic monthly totals were not detected for any cell.

Since many models require 6-hour precipitation amounts, the 24-hour amounts in each of the CMC cells were resolved to shorter periods. Since the 24-hour periods in this data base overlapped the preceeding and succeeding periods by 12 hours, 12-hour amounts were inferred. It was assumed that precipitation measured during any 12-hour period occurred during one constant 3-hour period, slightly longer than the average duration of an event in North America (5), beginning at the midpoint of the 12-hour period. Because precipitation duration could have a significant effect on simulated wet depositions, it was better to assume that the precipitation occurred between 0600 - 0900 and 1800 - 2100 GMT than to spread the precipitation evenly across the 12 hour period.

Monthly precipitation grids were generated for quality assurance purposes. These grids were compared to monthly analysis maps of the raw data, and indicated the proper placement of the relative maximum and minimum amounts. However, the values of these grid extremes consistently were closer to the mean, which was a result of the spatial averaging. The grid extremes differed from the map extremes by approximately 10 percent.

Annual precipitation amounts at 72 eastern North American precipitation chemistry sites were compared with the precipitation for the 127-km CMC grid cells containing each site (Debbie Palka, Program Resources, Inc., private communication, 1985). As Ruff et al. (6) reported in an independent study, grid amounts, in general, did not compare well with the site measurements. Figure 2 illustrates this by comparing histograms of the annual site and grid precipitation amounts.

The grid amounts tended to be lower than the site amounts. The medians for the site and grid amounts were 910 and 815 mm, respectively. The first and third quartiles were much closer to the median for the grid amounts, indicating less variability than was found in the measurements. In essence, data averaging operations to derive precipitation amounts for a given area smooth the measurements. The significance of the smoothing has yet to be quantified.

Mixing Heights. Monthly average maximum and minimum mixing heights were determined for each cell of the ISDME grid configurations. The monthly grids were derived from 127-km seasonal grids, which were generated from analyses of several years of rawinsonde data (7,8).

Sulfur Emissions Data

The sources of the ISDME sulfur dioxide emissions data were the 1980 National Acid Precipitation Assessment Program (NAPAP) Task Group B emissions inventory (Version 2.0) and the Environment Canada emissions inventory used in the Phase III MOI activity. Approximately 85% of the point source emissions in the latter inventory were estimated from 1980 source data (9). Canadian area source emissions, comprising only 6% of the country's annual total, were derived from 1978 source data. Over 95% of the United States emissions were derived from 1980 source data (10).

The overall precision of the Canadian emissions inventory was estimated to be 6.1%; for the United States inventory the precision has yet to be determined. However, the precision of the United States MOI emissions inventory, based on the same initial data base, was estimated to be 2.3% (10).

Seasonal sulfur dioxide emissions from United States and Canadian point and area sources were apportioned to the appropriate cells of each ISDME grid. For point sources, emissions were simply allocated to the cell containing the source.

Canadian area source emissions already were available on the 127-km grid. To allocate these emissions to the other grids, emissions first were assigned to virtual sources in the lower left corners of each cell. These emissions were allocated to the cells containing the virtual source. On the other hand, United States area sources, whose emissions were aggregated on the county level, were apportioned to grid cells on the basis of the population distributions as determined from the 1970 Census Bureau data (11). Figure 3 illustrates the 80-km grid of 1980 sulfur dioxide emissions.

The emissions were further apportioned to 3 layers (Figure 4). Area source emissions were allocated to the lowest layer. Point source emission apportionment was based on climatological effective plume rise approximations (12) determined from stack parameters, monthly climatological meteorological data and Briggs' plume rise equations.

The following discussion explains the point source apportionment procedure. The United States point source emissions, approximately 70% of which are from power plants, were divided into 3 representative categories based on physical stack heights of 190, 220 and 340 m. Canadian point source emissions were divided into 2 categories of primary metal plants, pulp and paper plants, 3 categories of power plants based on physical stack heights of 91, 150 and 198 m, and 4 categories of oil refineries. The frequency of occurrence of stack heights in different intervals formed the basis of this decision.

An average effective stack height for each category was computed for each season using stack parameters, stability frequency distributions, Briggs' plume rise equations and associated mean wind speeds on a monthly basis at each cell on the 127-km grid configuration. Rather than examining each grid cell individually, stability frequency distributions over 3 broad geographical regions were used. These regions were coastal, central industrialized and southern.

The range of computed effective stack heights over the year was found to be 2 to 3 times the physical stack heights. As a conservative estimate, an effective stack height twice that of the physical stack height was assumed throughout the year. For the many United States point sources with no reported stack height in the data base, the physical stack height was assumed to be the national average height for that type of source.

Effective stack heights for United States and Canadian power plants ranged from 300 to 750 m and 200 to 400 m, respectively. Effective stack heights for the single largest emitters in both countries exceeded 700 m.

Summary and Conclusions

In the past, model simulations have focused on the modeling aspects themselves; processing model input data and assessing their appropriateness for model applications has not received the attention they deserve.

As one objective of the International Sulfur Deposition Model Evaluation, standardized grids of 1980 North American meteorological and sulfur dioxide emissions data were generated. Wind grids for the 1000 and 850-mb levels were processed from dynamic model results in lieu of rawinsonde data to yield better analyses between observation times. Precipitation grids with a 3-hour resolution were estimated from 24-hour, 127-km North American grids. Maximum and minimum monthly mixing height grids were

processed from analyses of several years of rawinsonde data. Finally, sulfur dioxide emission grids were processed for 3 layers using the latest available emissions estimates.

There is no doubt that meteorological and emissions data processing techniques, as well as the available data themselves, need improvement. The ISDME precipitation data processing technique was used in lieu of an existing sophisticated technique, because the latter used a data set found to possess serious deficiencies. Once these deficiencies are corrected, a more sophisticated approach can be applied.

As for the emissions data processing, once the appropriate stack parameters have been defined and validated in the emissions data inventories, more accurate effective stack heights can be determined.

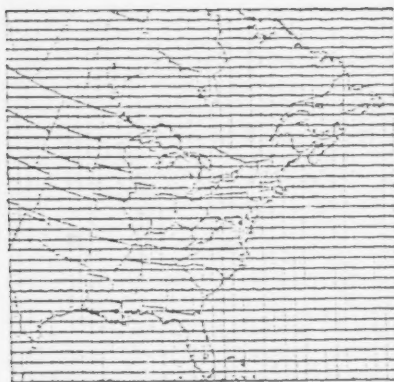
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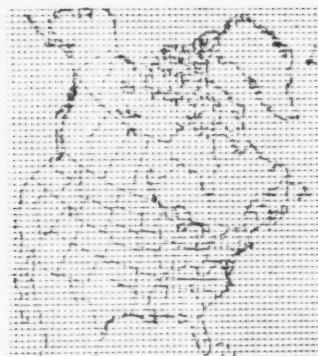
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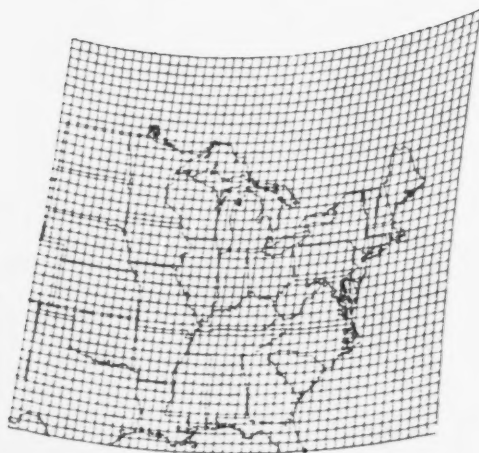
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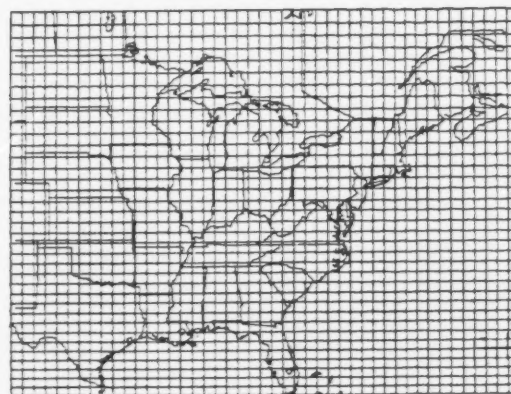
(a)



(b)



(c)

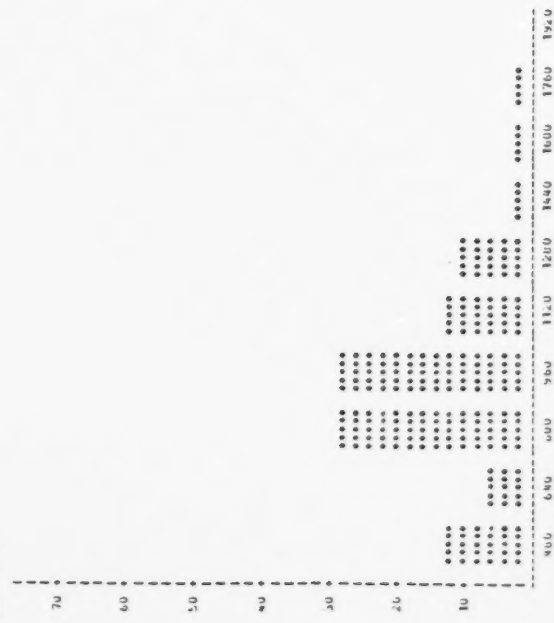


(d)

Figure 1. The 4 ISDME model grid configurations for which model input data have been processed - the 38-by-37 window of the full 127-km CMC grid (a); the full 52-by-58, 127-km polar stereographic CMC grid (b); the 46-by-41, 70-km Universal TransMercator ENAMAP grid (c); and the 45-by-36, 80-km latitude, longitude ACID grid (d).

Site Measurements

PERCENTAGE



a

Grid Cell Averages

PERCENTAGE



b

Figure 2. Percentage frequency distributions of the 1980 annual precipitation amounts (mm) at 72 eastern North American precipitation sites (a) and the 127-km grid cells encompassing these sites (b).

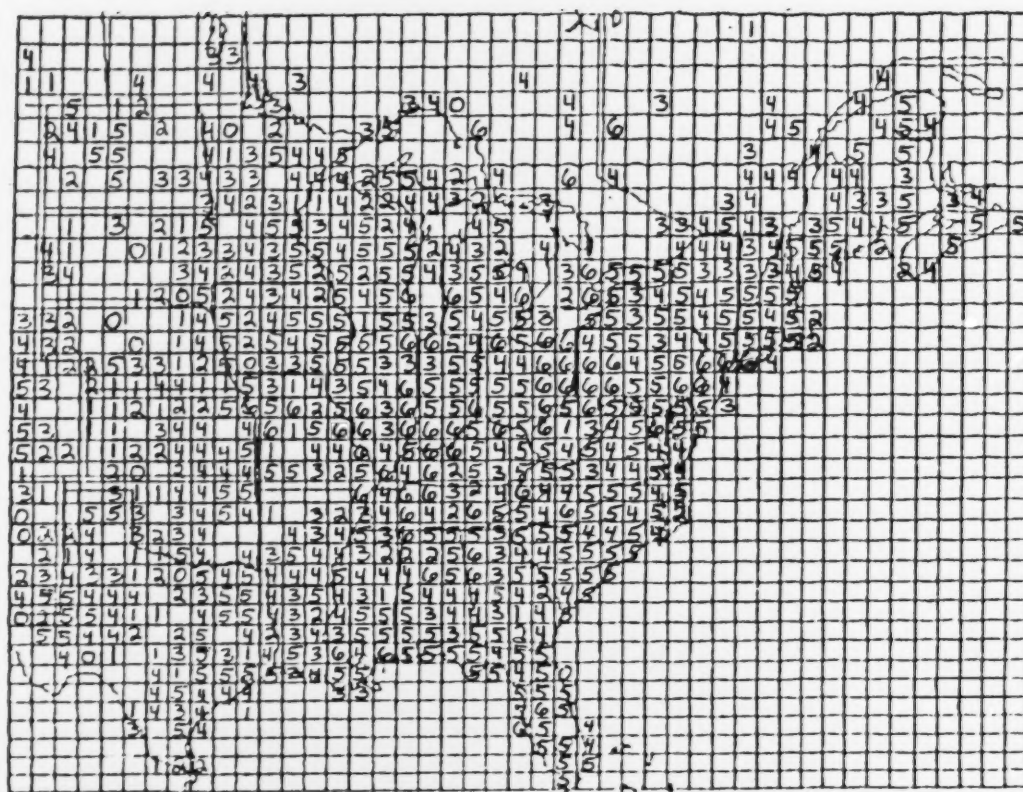


Figure 3. The spatial distribution of the 1980 ISDME annual SO₂ point and area source emissions across the ACID model grid configuration. Orders of magnitudes (tonnes SO₂) are indicated (e.g., a "6" indicates an emissions rate of between 5.0×10^5 and 4.9×10^6 tonnes).

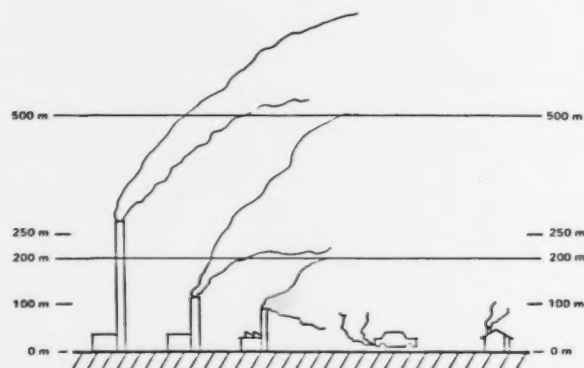


Figure 4. The 3 layers in which SO₂ emissions are injected. Heights are relative to ground level.